Non-Fermi liquid behavior in $Ce_{1-x}Y_xRhIn_5$

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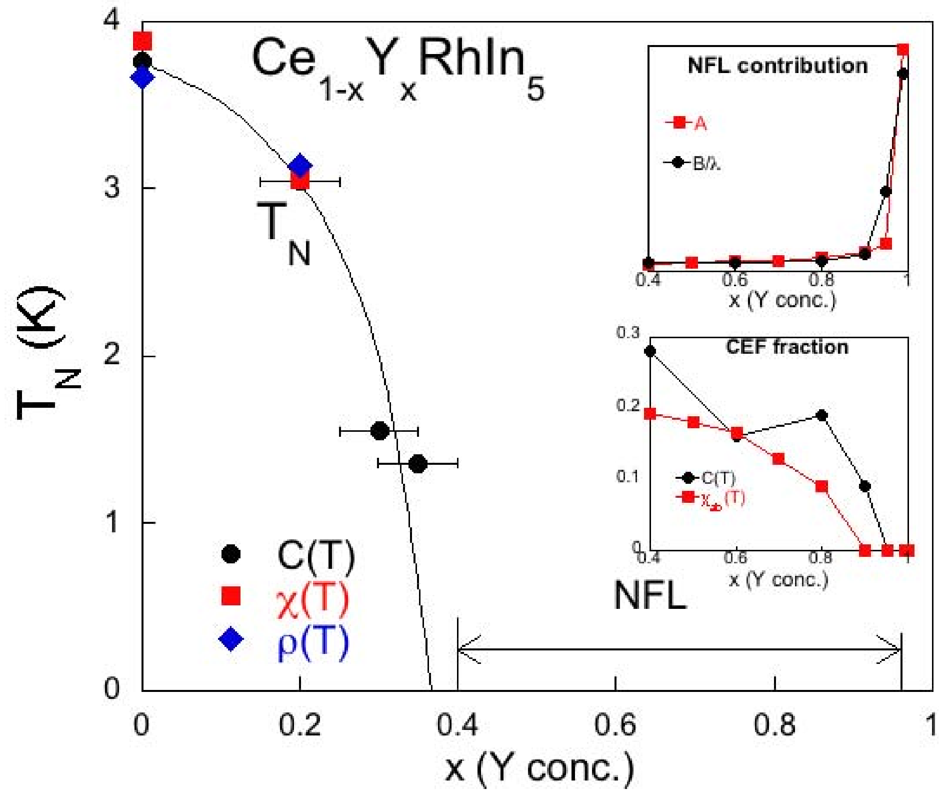
• Antiferromagnetism (AFM) in $CeRhIn_5$ is suppressed as nonmagnetic Y ions are substituted for Ce ions. The Néel temperature T_N appears to vanish at an Y concentration x near 0.4 (quantum critical point – QCP).

• Non-Fermi liquid (NFL) behavior is observed over a broad range of Y concentrations x between 0.4 and 0.99. Power law fits to the magnetic susceptibility $C_{ab}(T)$ reveal a nearly constant value of λ for all concentrations with a diverging prefactor A as Y concentration x is increased, while for the specific heat C(T), λ decreases and B/λ diverges with increasing x.

• For the dilute Ce concentration limit, C(T) is better described by the relation $C(T)/T = -(D/T_o)\log(T/T_o)$, rather than a power law.



Néel temperature T_N versus Y concentration x. Upper inset: NFL contributions to $\chi_{ab}(T) = AT^{-1+\lambda}$ and $C(T)/T = BT^{-1+\lambda}$. Lower inset: decrease of Ce ion contribution to CEF effects with x.

Fermi liquid theory has served as the basis of our understanding of metals since the late 1950s. In this theory, the interactions between mobile electrons in a metal cause them to behave at low temperatures as if they had a larger mass. These electrons, referred to as "quasiparticles," have effective masses of up to several times that of a bare electron and can account for the low temperature behavior of ordinary metals like aluminum, copper, platinum, etc. In the 1970s, compounds containing rare earth and actinide elements such as $CeAl_3$ and UPt_3 were found to have quasiparticle masses up to <u>several</u> <u>hundred</u> times greater than that of the bare electron and properties that still conformed to Fermi liquid theory. However, in the early 1990s, several materials were found such as $Y_{0.8}U_{0.2}Pd_3$ and $CeCu_{5.9}Au_{0.1}$ whose low temperature properties deviated strongly from those of a Fermi liquid, indicating a breakdown of the Fermi liquid paradigm. Since then, many more materials that display this so-called "non-Fermi liquid" (or NFL) behavior have been discovered. In addition to NFL behavior, some of these materials exhibit an unconventional type of superconductivity that cannot be described by the standard BCS theory that successfully accounts for superconductivity in ordinary metals such as Sn and Pb, for example. These NFL materials and other exotic materials with "strong electron correlations" are causing us to modify our views of metals and are potential candidates for technological applications: e.g., thermoelectric cooling, magnetic recording, superconducting applications such as high field magnets, generation, transmission, and storage of electrical energy, magnetic levitation of high speed trains, medical diagnostics, etc.

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Broader impact on society:

For nearly half a century, Fermi liquid theory has been the basis for the understanding of metals. However, recent investigations of complex materials, such as high T_c cuprate superconductors, certain f-electron materials, and low-dimensional conductors, reveal that the physical properties of these materials do not obey the Fermi liquid paradigm. The non-Fermi liquid (NFL) behavior these materials exhibit is believed to be associated with a quantum critical point (QCP), a critical value of a control parameter such as composition, pressure, or magnetic field where a phase transition occurs at 0 K. New and novel phases of matter with unusual properties including unconventional SC and complex magnetic ordering may be found in the neighborhood of QCPs and could have properties that are useful in technological applications.

An example is high T_c superconductivity in cuprates, which many researchers believe is associated with a QCP. Quantum critical behavior is a challenging unsolved problem in condensed matter physics.

Education/research:

Three undergraduate students (Yvonne Edmonds, Patrick Johnson, and Stella Kim), three graduate students (Vivien Zapf, Todd Sayles, and Neil Frederick), and a post-doc (Pei-Chun Ho) have been in involved in this work. Yvonne Edmonds was an REU student, and will begin graduate study at Stanford University this fall. Stella Kim, a senior, and Patrick Johnson, a sophomore, are currently undergraduate students at UCSD. Vivien Zapf received her Ph.D. in 2003, and is currently working at LANL, while Neil Frederick, Todd Sayles, and Pei-Chun Ho are still members of our group, and are performing related experiments.